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## Plant Doctors: A Critical Need

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There is little doubt among agricultural scientists about the gravity of the challenges posed by pests and suboptimal environmental conditions including global climate change, and movement of invasive species to providing sustainably produced food, fodder, fiber and bioenergy for an ever-increasing world population. Current management of pests (including arthropods, plant pathogens and weeds) in many cases is solely based on the use of pesticides; but reliance on this single strategy may lead to pesticide misuse and the development of pesticide resistance. Agricultural pesticide misuse and overuse has been documented in many regions including Southeast Asia. Concern about the impact of crop production practices on the environment may lead to a prescriptive approach to agriculture as is currently being practiced in California, USA and under discussion in Taiwan. *Plant Doctors*, plant health practitioners academically trained across agricultural science discipline, including both pest-related (entomology, plant pathology, nematology, weed science, and other pests) and plant-related (agronomy, horticulture, soil and water science, etc.) disciplines, have become key links in sustainably meeting these production challenges. Since 1999, this new approach to training plant health professionals has been adopted by 11 universities in the USA (Florida, Nebraska, Ohio) and Asia (Japan, South Korea and Taiwan), and three are in development in Egypt, mainland China, and Thailand. More than 1,800 plant doctors have been trained, many of whom have developed exceptional careers as practitioners in diverse areas including sustainable crop production, food security and safety, crop consulting, extension, associated agriculture industries, landscape plant health, invasive species management, teaching and research.

**Keywords:** Plant medicine, Plant health management, Interdisciplinary training, Integrated crop management, Sustainable agriculture, Food safety, Food security

### Introduction

There is little doubt among agricultural scientists about the gravity of the challenges posed by pests and suboptimal environmental conditions including global climate change, and movement of invasive species to providing sustainably produced food, fodder, fiber and bioenergy for an ever-increasing world population. (Agrios, 2005; Culliney, 2014; FAO, 2015; Gallandt and Weiner, 2015; Pinstrup-Andersen, P. 2001; USEPA,

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2015). It has been estimated that the global demand for food will necessitate a 70% increase in production by 2050 (FAO, 2010). Global movement of invasive species leading to reduced biodiversity in biotic resources and damage to crops is another increasingly important problem (Huber *et al.*, 2002). Concern about the impact of crop production practices on the environment may lead to a prescriptive approach to agriculture as is currently being practiced in California, USA (agricultural pest control advisers), and under discussion by the legislature of Taiwan in the form of the “Plant Doctor Act” (Dr. T. K. Wang, Taiwan Bureau of Animal and Plant Health Inspection and Quarantine, personal communication, July 6, 2015). Information on the need for rigorous, interdisciplinary training of plant health practitioners, *Plant Doctors*, to meet these challenges has been previously presented (Agrios, 2001; Capinera, 2000; Hein and Hodges, 2013; Hein and McGovern, 2009).

The term *Plant Doctors* is defined here as those plant health practitioners academically trained across agricultural science discipline, through coursework and internships in both pest-related (entomology, plant pathology, nematology, weed science, and other pests) and plant-related (agronomy, horticulture, soil science, etc.) subjects, to directly serve agriculture and the general public, through the prevention, diagnosis and management of plant health problems. Also, when I refer to plant pests and their management I do so in this broad sense.

The objectives of this paper include examining the development of the plant doctor concept, the training programs that have been established, the impact of plant doctors, and possible future directions for this emerging profession including increased inter-program communication and cooperation.

### **Pioneer practitioners, programs and organizations**

A number of pioneer practitioners, primarily plant pathologists and entomologists, have had a major influence on the development of the plant health profession. After completing a Ph.D. in plant pathology at Cornell University, Dr. Cynthia Westcott (1898-1983) established a private practice in 1933 centered in the New York metropolitan area, encompassing the diagnosis and management of plant problems in primarily private landscapes caused by pathogens and arthropods (Horst, 1984). Over a period of 30 years, she presented nearly 1000 lectures, conducted diagnostic clinics in department stores, taught courses in botanical gardens, wrote regular columns on plant problem diagnosis for the *New York Times* and *Home & Garden Magazine*, and authored such references as *Westcott's Plant Disease Handbook*, *The Gardeners Bug Book*, *The Plant Doctor* and *Plant Doctoring is Fun*. Because of these efforts, and within 10 years after starting her practice, she became known to the general public as *The Plant*

*Doctor*, and was the prototypical practitioner of plant pathology in the United States.

Another plant pathologist, Dr. Robert S. Cox (1919-1999) focused his efforts on assisting Florida vegetable and ornamental growers with their plant disease problems. In 1957, following brief employment at a research center of the University of Florida, Cox became the first independent crop consultant in the state. He scouted tomato fields and was intensively involved in helping farmers develop management practices for devastating fungal and bacterial diseases including Fusarium wilt [*Fusarium lycopersici* f. sp. *lycopersici* W.C. Snyder & H.N. Hansen, (1940)] and bacterial spot (*Xanthomonas* spp.), respectively. At meetings of the American Phytopathological Society (APS) Cox was a vocal proponent of recognition of crop consulting as a profession. Furthermore, in his book *The Agricultural Consultant* he advocated interdisciplinary training in plant protection that influenced a number of universities in the USA to adopt this approach (Cox, 1982).

Dr. Earle S. Raun (1924-2009) worked as an entomologist with the USDA for 20 years, and 8 years with the University of Nebraska, first as chair of the Department of Entomology, and then as Associate Director, of the Nebraska Cooperative Extension Service. In 1974, Raun became the first independent crop consultant in the Midwestern USA. He and his colleagues conducted ground-breaking research on the European corn borer [*Ostrinia nubilalis* (Hübner) (Lepidoptera: Pyralidae)] and Western corn rootworm [*Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae)]. But perhaps even more importantly, he became a founding member and first president of the National Alliance of Independent Crop Consultants (NAICC). Raun was a strong supporter, as was the NAICC, of interdisciplinary training in plant health and the regional establishment of plant doctor programs in the USA including those subsequently established at the University of Florida (UF) and University of Nebraska-Lincoln (UN-L) (Bradshaw and Marquart, 1990). Dr. John L. Capinera, who later became chair of the UF Department of Entomology and Nematology and one of the key figures in the establishment of the Plant Medicine Program there, was influenced by a talk presented by Raun on the topic (J. L. Capinera personal communication, September 14, 2015).

Over a 40-year period, this holistic, interdisciplinary approach to training plant health practitioners was espoused in the writings of many plant pathologists (Browning, 1998; Horsfall, 1959; Kendrick, 1984; Merrill, 1979; and Tammen and Wood, 1977). Perhaps the strongest proponent of this approach was Dr. J. Artie Browning (1923-2013) who served as a researcher and teacher at Iowa State University for 28 years, and head of the Department of Plant Pathology and Microbiology at Texas A&M University for 9 years. Browning combined brilliance in theoretical and practical breeding for disease resistance in cereal crops, primarily against oat rust

[*Puccinia coronata* Corda, (1837)], with unbounded enthusiasm for what he felt was a necessary change in the training needed to deliver effective and sustainable technology to farmers. Like Raun, he was an early and ardent supporter of the establishment of plant doctor programs such as those later developed at UF and UN-L. In his presidential address at the annual meeting of the APS in 1982 he recommended that the society join its sister agricultural science disciplines in establishing plant doctor programs (Browning, 1998). As he later stated in his paper *One Phytopathologist's Growth through IPM to Holistic Plant Health: The Key to Approaching Genetic Yield Potential*:

“Thus, plant doctors give hope for approaching attainable yields and feeding a hungry world. The plant health movement has the potential to effect the greatest change in world agriculture since the Green Revolution, and the D.P.H./M to become plant agriculture's most important single degree program.” (Browning, 1998)

A number of plant health-related educational programs and organizations also helped to provide the ethos in which the plant doctor concept evolved. The Integrated Pest Management (IPM) movement initiated by Stern et al. in 1959 led to new multicomponent tactics for pest control and spawned training programs in universities worldwide that combine arthropods, plant pathogens, and weeds such as the MPPPM program at the University of Georgia. Development of the Integrated Crop Management (ICM) concept then followed which additionally recognizes the importance of managing all aspects of crop production, pest management as well as cultural practices, coupled with an awareness of agriculture's environmental impact to achieve sustainability (Agra CEAS Consulting, 2002). Combination of the disciplines of entomology, plant pathology and weed science into a single research unit, the Institut für Phytomedizin occurred at Hohenheim University in Germany in 1939, prefiguring the later integration of the different pest groups into Plant Medicine Departments in Asia. These organizations acknowledge the advantage of grouping plant pest management into a single research unit and thereby achieved at least partial defragmentation of agricultural science.

Following in the footsteps of Westcott, Flower Time, Inc./Frank's Nursery & Crafts, Inc. (FNC), once the largest garden center chain in the USA, operated an integrated plant diagnostic service for home owners in the 1980s. This service was delivered by in-store specialists equipped with stereo microscopes and pertinent references, and trained by the company's Horticulture and Diagnostics Department (HDD) in regionally appropriate pest diagnosis and management and horticultural practices (McGovern and Willard, 1988). The educational background of these plant health specialists ranged from the A.A.S. to Ph.D. degrees in horticulture, pest management

or related disciplines, with the majority possessing bachelor's degrees. The service also included basic and advanced soil testing for diverse landscape sites ranging from vegetable gardens to turfgrass. This 13-state, 130-store, computer-linked diagnostic network was supported by a central clinic and reference library in Detroit, Michigan, which included all of Westcott's publications. As director of the HDD, I recognized the need for interdisciplinary training to ensure delivery of effective plant health advice to our clientele. Therefore, I listened with great interest when Dr. George N. Agrios, chairman of the UF Department of Plant Pathology, delivered his presidential address at the 1991 annual APS meeting describing the plans to establish the Plant Medicine Program at that university.

### **Plant Doctor Programs**

Beginning with the program established after multiple attempts by Drs. Agrios, Capinera and Jerry M. Bennett at UF in 1999, plant doctor programs have been initiated at a total of 11 universities in the USA and Asia [Japan, South Korea (the Republic of Korea) and Taiwan (the Republic of China)], and three are under development in Egypt, China (the People's Republic of China) and Thailand (Table 1). The academic level of these programs ranges from bachelor's to master's and doctoral degrees. In addition, some of the plant medicine departments also offer traditional M.S. or Ph.D. degrees that are based on research conducted in a single plant pest discipline. Joint M.S. or Ph.D. degrees are options for D.P.H. and D.P.M. students at UN-L and UF, respectively, and a joint D.P.M.-Ph.D. is being planned at Mansoura University in Egypt.

It is not surprising that differences exist between these plant doctor programs given their different regional socioeconomic environments, traditions and needs, and because plant medicine is still in its formative stage. Its sister professions of human and animal medicine took many years to standardize M.D. and D.V.M. training, respectively, and still deal with the concordance of regional/national differences in training and degree names. For example, in the U.K. and a number of other countries following that tradition, the Bachelor of Medicine (M.B.) and Bachelor of Surgery degrees (ChB), are the first two professional degrees awarded upon graduation from medical school. The M.B./Ch.B. are generally awarded jointly after completion of what is analogous to a 5-year combined undergraduate-graduate program of study. Browning (1998) suggested that individuals with bachelor's degrees in plant medicine be considered "paraprofessionals". This appears to the case in Japan where the B.S. in Clinical Plant Science qualifies the recipient for recognition as an "Associate Tree Doctor" and "Associate Nature Restoration Promoter" (see *Certification/ licensure below*). However, this approach may not adequately consider the rigor and extent of the B.S.P.M. degrees in all regional contexts.

Equivalency determination of plant doctor training, including the issue of academic level, is beyond the scope of this paper. Procedures for certification and licensure of plant doctors will be the work of future practitioner groups, legislators and academicians on a regional basis.

Despite their differences, plant doctor programs share important common characteristics including a mandatory interdisciplinary core curriculum that encompasses both pest- and plant-related disciplines, and a practicum or internship component. Students in all of the programs can specialize through their practicums/internships and elective courses in many plant health areas including sustainable crop production, food security and safety, crop consulting, extension, landscape plant health management, invasive species management, associated agriculture companies, teaching/research, and related fields.

All of the undergraduate plant doctor programs are housed within departments of Plant Medicine, or in the case of Hosei University (HU), in the Department of Clinical Plant Science. The master's degree programs at National Chung Hsing University (NCHU) and National Taiwan University (NTU) are divisions of their College of Agriculture and Natural Resources and College of Bio-Resources and Agriculture, respectively, and the Master of Plant Health Management is jointly administered through the Departments of Entomology and Plant Pathology at Ohio State University. The Doctor of Plant Health Program at the UN-L is considered a graduate professional degree program within the College of Agricultural Sciences and Natural Resources, and the UF Plant Medicine Program is a graduate program within the College of Agricultural and Life Sciences.

Plant doctor students have funded their degrees in a variety of ways. Undergraduates in South Korea are on scholarships or are self-funded, while those in Japan and Taiwan are primarily self-funded. Students seeking M.S.P.M. degrees in Taiwan find support through scholarships and research and teaching assistantships. D.P.H. and D.P.M. students have funded their degrees through first-year assistantships, fellowships, part-time research positions, dual M.S. and Ph.D. degrees, student loans and combinations of these strategies. Direct agriculture industry/employer support of students has occurred but has been rare; one DPM student at UF and three MPH students at Ohio State University were funded by their employers. Industry-academia partnerships would seem a logical step in training effective future employees or upgrading the educational level of current employees. Such relationships require flexibility on the part of both plant doctor programs and industry.

### **Impact of Plant Doctors**

To date, over 1,800 plant doctors have been trained with the great majority at the bachelor's level. In general, the graduates with B.S.P.M.

degrees have had a lower employment rate in plant/crop health (30-80%) than those with master's or doctoral degrees (80-100%). Notably the graduates of the UF and UN-L programs commonly have multiple job offers at degree completion. Graduates with B.S.P.M./B.S.P.C.S. degrees are employed in food production, extension, landscape plant health (especially arboriculture), associated agriculture industries (agrochemicals, seed companies, etc.). A significant number of those with undergraduate degrees (~30%) pursue graduate level plant doctor or research-based degrees. Representative examples of the exceptional careers developed by plant doctors, especially those with D.P.H. and D.P.M. degrees, are provided below; in a number of cases the information is in the words of the plant doctors themselves. Since most data is available for individual plant doctors with graduate degrees from the programs that have existed the longest, their profiles predominate.

### ***Sustainable crop production.***

*Dr. Daniel Sonke, D.P.M.* was the Program Manager with Protected Harvest where he oversaw the development of sustainable production standards, the certification process and third party auditing. He continued these types of activities as Senior Scientist with SureHarvest, Inc. In these positions he developed specific sustainable agriculture programs for fruits, vegetables, mushrooms, and nuts, including the California Almond Sustainability Program. He is currently the Manager of Agriculture Sustainability Programs for Campbell's Soup Company, the world's largest soup maker, valued at \$14.5 billion (Forbes, 2015). Based in Sacramento, CA, Dr. Sonke develops the company's approach to sustainability in agriculture by working with vegetable farmers and other ingredient suppliers to track, encourage and enable sustainability progress. He also serves as a resource for the company on agricultural issues.

*Dr. Haley Oser, D.P.H.* is employed in Golden, Colorado as an agronomist with the Coors Brewing Company, a regional division of the world's seventh-largest brewing company, the Molson-Coors Brewing Company. Dr. Oser provides sustainable production guidance for the company's barley growers.

*Dr. Clay Pederson, D.P.M.* was the Farm Manager for nearly 5 years of Black Gold Farms in Live Oak, FL responsible for the day to day production of over 800 ha of potatoes as well as small grains. The Black Gold Farms' Florida location and all other locations are global Good Agricultural Practices (G.A.P.) Certified to ensure the use of sustainable practices, both economically and environmentally. The use of soil moisture probes, remote irrigation controls, petiole sap testing, cover crops and an intense IPM program are but a few of the many tools employed to help increase sustainability. Dr. Pederson is currently applying those skills as

Managing Director of Agromillora Florida, Inc., Wildwood, FL which is a citrus nursery focused on commercial production of citrus rootstock liners with sanitary and genetics assurance.

***Food security.***

*Dr. Adam Silagyi, D.P.M.* served for 2 years as the Agricultural Development Officer (ADO) of the United States Agency for International Development (USAID) in Guatemala. Among his responsibilities in Guatemala was service as the Agreement Officer's Representative managing one of USAID/Guatemala's Feed the Future (FTF) partners, a Global Development Alliance, and a four-year \$2.4 million project working in rural value chains and nutrition that leveraged nearly \$1 million in private-sector funds. Dr. Silagyi next was the FTF Team Leader for 2 years as the ADO of USAID in Ethiopia. There he was responsible for managing a multiyear diverse food security, nutrition and resiliency portfolio of \$270 million, as well as the overall coordination, reporting, monitoring and evaluation of the Ethiopia Mission's FTF program. He is currently USAID Agriculture/Food Security Officer, Zimbabwe

*Dr. Tara Wood, D.P.H.* worked for 2 years at the Norman Borlaug Institute for International Agriculture at Texas A&M University as the Program Coordinator for Sub-Saharan Africa. She is currently the Deputy Chief of Party on a USAID-funded, International Fertilizer Development Center-led Agricultural Technology Project in Ghana.

***Food safety.***

*Dr. Sarah Taber, D.P.M.*, based in Florida, is involved in a number of food safety activities. She performs food safety audits and consulting through her consultancy, Boto Waterworks LLC. Among her consulting projects is the North Country Clearwater company under development in Wisconsin, projected to be one of North America's largest aquaponics facilities, which will combine trout, salmon and lettuce production using state of the art engineering principles and food safety designs. [Aquaponics refers to systems that combine aquaculture (raising aquatic animals such as fish, shrimp, etc.) with hydroponics (cultivating plants in water)].

***Crop consulting.***

*Dr. Rafael A. Vega, D.P.M.* works as a consultant with New England Fruit Consultants (NEFCON) in Montague, Massachusetts. Established in 1982, NEFCON has apple-producing clients throughout the northeastern USA. Dr. Vega has become an integral part of this consulting firm with a set of his own clients, and is the manager of NEFCON's 3-ha research apple



orchard. He is in the process of becoming certified as an independent crop consultant through the NAICC. Dr. Robin Spitko Ph.D., president of NEFCON, indicated that plant doctor training provides an ideal background for crop consulting:

“There is a shortage of individuals with the rare mix of advanced scientific training and broad agricultural knowledge who are able to work as crop consultants to farmers. Crop protection systems like IPM work most efficiently when farm advisors have a broad understanding of the science and integration of multiple disciplines, such as the UF Plant Medicine Program provides.”

*Dr. Lacey Mount, D.P.M.* is a crop consultant with Dellavalle Laboratory, Inc. an environmental/agricultural laboratory and consulting firm located in the San Joaquin Valley with clientele worldwide. She advises farmers in the Fresno, California area on sustainable crop production through written soil amendment and fertilizer recommendations based on plant tissue, soil and water sampling and analysis, and irrigation monitoring.

#### ***Extension.***

*Dr. J. Stacy Strickland, D.P.M.* is Multi-County Extension Director for Hernando and Sumter Counties, for the University of Florida (UF)-IFAS where hay, nursery stock and oranges are the major crops. He is responsible for general agriculture programming and the supervision of 11 agents and six staff members. Dr. Strickland is also the Agriculture Program Leader for these counties directing three urban horticulture agents, one livestock, and two commercial horticulture agents.

*Dr. Christian Miller D.P.M.* is also an extension agent with the UF-IFAS. He serves the vegetable and tropical fruit growers in Palm Beach County by providing information on a wide range of issues including labor shortages, marketing, pest management, new varieties and sustainability. Dr. Miller views himself as an interface between growers and researchers in helping to develop programs to meet grower needs.

*Dr. Monica Cooper, D.P.M.* is Viticulture Farm Advisor with the University of California (UC) in Napa County, California. Napa's winery grape production drives the local economy and was valued at \$714 million in 2014 (Department of Agriculture, 2014). Dr. Cooper's clientele are vineyard managers, viticulturists, and agricultural pest control advisors. She collaborates with UC Faculty, Extension Specialists, Farm Advisors, USDA and state research scientists, and local industry groups to develop research and educational programs. These programs focus on climate change, invasive species, integrated pest management and sustainability.

Two graduates of the Ohio State University (OSU) Master of Plant Health Management (M.P.H.M.) program are working in extension in Ohio.

*Mary Griffith* is an OSU Extension Educator in the area of Agriculture and Natural Resources in Madison County. She is interested in promoting natural ecosystem health and addressing risk in specialty crop production through education and outreach related to agricultural management practices. *Jason Hartschuh* was promoted to Extension Director in Crawford County with OSU Extension after earning his M.P.H.M. degree. He also works in Agriculture and Natural Resources with an emphasis on agronomic crops.

### ***Landscape plant health.***

*Dr. Christopher Boorman, D.P.H.* has what many in arboriculture would consider a “Dream Job” – he is an arborist with the New York City Urban Forestry Service. Among his responsibilities is oversight of the health of more than 20,000 trees in the city’s 341-ha Central Park, which receives millions of visitors annually.

*Dr. Stephanie Bledsoe, D.P.M.* is a Regional Director of Agronomy with Mainscape, Inc. a full service landscape maintenance and lawn care company ranked 19th in the USA. She is responsible for: supervising all of Mainscape’s agronomy personnel in the southeastern USA from the Carolinas to south Florida; devising agronomic programs (fertilizers, pesticides, growth regulators); educational and training program development; diagnosis of plant problems and solution implementation; and customer education programs. Dr. Bledsoe places a high priority on personnel education and a systematic approach to plant diagnostics in the field in order to reduce pesticide use and impact on the environment.

*Dr. Mary Sullivan D.P.M.* and Massachusetts Certified Landscape Professional (MCLP) is passionate about the health and beauty of landscapes. She is an Account Manager with NatureWorks Landscape Services, Inc. based in Walpole, Massachusetts. The most important aspect of her position is developing teams of highly motivated plant health providers who create outstanding properties in an environmentally compatible manner.

### ***Associated agriculture industries.***

*Dr. Dori Porter, D.P.H.* is employed as a Production and Processing Technology (PPT) Parent Characterization Scientist working on corn with Syngenta in Seward, Nebraska. Dr. Porter manages early stage inbred corn characterization projects across multiple sites, including experimental design, logistics management, consultation on project execution, workload assignments, data collection, and statistical analysis.

*Mr. Yuki Arinami, B.S.C.P.S.* is among the first graduates of the Hosei University Clinical Plant Science Department. He conducts field research for the Japan Crop Protection Association (JCPA) on the integrated

management of vegetable pests, including evaluating a new fungicide to manage powdery mildew in bell pepper. The JCPA is a non-profit organization of Japanese manufacturers, formulators and distributors of agricultural crop protection products, representing more than 90 companies. JCPA members manufacture, sell and distribute 95% or more of such products in the country.

*Dr. Laura Dotterer, D.P.H.* is employed by DuPont-Pioneer, a large US company that produces hybrid and genetically modified seed for agriculture. She first worked as an *Emerging Leader* in Integrated Operations Education in Dysart, Iowa, where she helped to educate and train Pioneer's production agronomists through a variety of projects. Recently Dr. Dotterer transitioned into a Global Business Product Steward role in DuPont Crop Protection based in Wilmington, DE. She is conducting product stewardship reviews on new and existing products with a main focus on the herbicide portfolio.

*Dr. Brianna Reeves, D.P.M.* was first employed by BASF as a Technical Marketing Specialist to work across the USA in all aspects of bringing new fungicides for row crops to the market. She is currently an Innovation Specialist for the company in North Carolina and Virginia.

"In this role I interact with growers on a daily basis about agronomics as well as all types of pests in their crops. My goal as an Innovation Specialist is to be a trusted agronomic advisor to growers in my geographic area, providing them with sound knowledge and advice based on the latest science. The diversity of topics studied in the D.P.M. program allows me to think critically and outside of the box when working with growers to solve a problem on their farm. I take pride in the fact that I can use my knowledge to help in providing innovative solutions to farmers so that they can get the most out of every acre."

*Dr. Anthony Barbaglia, D.P.M.* is a Technology Development Representative with Monsanto (Seminis), the largest producer of fruit and vegetable seeds in the world. He functions as a liaison between research and development (breeding) and the company's commercial teams (sales and marketing). He currently covers seven states in the Midwestern USA for the seed company. Dr. Barbaglia conducts field trials across the territory involving several species including: sweet corn, watermelon, cucumber, tomato, bell pepper, zucchini, and green bean.

"Product development and advancement to commercialization is a large part of Seminis' Technology Development Organization. Through field trials, I recommend products to be advanced for commercial sales. Through trial work, collaboration with universities, grower education and knowledge transfer we can demonstrate the benefits of our products. An example would be a transgenic line of sweet corn products that is herbicide resistant and also has below ground and above ground worm control. This can help to reduce the number of insecticide applications needed per season."

*Dr. Oscar Ruiz, D.P.M.* and Certified Professional Agronomist (CPAg) is Lead Agronomist with Waypoint Analytical, Inc. (WA), a conglomerate of agricultural and environmental laboratories based in Memphis, Tennessee, with facilities in 11 locations in the USA and Mexico. He supervises and supports the agronomic divisions in: Memphis; Atlantic, Iowa; Richmond, Virginia; Champaign, Illinois; Guadalajara, Mexico, and northern and southern California. This entails overseeing and updating WA's agronomic recommendations and client technical support.

"I have had the opportunity to put to full use all the knowledge and experiences that the Plant Medicine Program has to offer. The skills developed in soil science, plant pathology, nematology, agronomy, weed science and entomology create a well-rounded foundation for any graduate. The knowledge base I have acquired has assisted me in making decisions that are directly affecting crop nutrient management, plant health, grain/fiber/oil/forage production throughout the United States and beyond. Without the training and experiences I received in the Plant Medicine Program I would not have had the qualifications for this position."

#### ***Invasive species management.***

*Dr. Kirk Martin, D.P.M.* functions as the Responsible Official for the Select Agent Plant Pathogen Program of the USDA/Animal and Plant Health Inspection Service/Plant Protection and Quarantine/Center for Plant Health Science and Technology (CPHST) in Beltsville, Maryland. These high consequence pathogens affect crops such as potato, corn, tomato, forage for livestock, wheat, rice and ornamental plants. Dr. Martin manages the select agent staff training, security risk assessments of staff, emergency drills, inventory, laboratory practices, transfers and identifications. He also oversees the operation of the CPHST plant pathogen Biosafety Level 3 laboratory and containment greenhouse.

*Dr. Leroy Whilby, D.P.M.* was the State Survey Coordinator for the Cooperative Agricultural Pest Survey (CAPS) Program of the Florida Department of Agriculture and Consumer Services, Division of Plant Industry in Gainesville Florida for about 5 years and was then promoted to Bureau Chief of Entomology, Nematology and Plant Pathology.

"Both positions involve preventing the introduction of diverse invasive species and require in depth knowledge in multiple plant pest areas. Due to the interdisciplinary training received from the Plant Medicine Program, I am able to carry out my duties in a rapid, comprehensive and holistic manner."

### ***Teaching/research.***

*Dr. Javier Garces, D.P.M.* is a Professor and Director of the Plant Science and Agricultural Technology Program at Valencia College in Orlando, Florida. His teaching responsibilities include Environmental Science, Introduction to Horticulture, Plant Pathology, Plant Physiology, and Greenhouse Operations/Management. A Sustainable Agriculture Production specialization has recently been added.

*Dr. Tim Durham, D.P.M.* is an Assistant Professor of Agronomy and the Agriculture Program Coordinator at Ferrum College in Franklin, Virginia. He has found that his interdisciplinary training has been an advantage in interacting effectively with colleagues of diverse academic disciplines. He further believes that because of their broad-based training D.P.M.s are uniquely positioned to make a lasting impact on the complex, interconnected issues of food security, population growth and sustainability.

*Dr. Tomás Chiconela, D.P.M./Ph.D.* is a Professor and the Dean of the College of Agricultural Science, Environment and Forests, Eduardo Mondlane University, Maputo, Mozambique. His research and teaching activities and funding accomplishments have been truly impressive and include biodiversity management [The Global Environment Facility (GEP) Small Grants Programme]; climate smart agriculture (HELVETAS, Swiss Intercooperation, and other organizations); improving the livelihood of women smallholder farmers (Bill & Melinda Gates Foundation Challenge Grant); and water governance, and plant disease management (EAU4 Food Project - CIRAD, a French agricultural research and international cooperation organization). He acknowledged the usefulness of the D.P.M. degree:

“The D.P.M. is a mind opening degree for plant health professionals. It gives them the tools to deal with all kinds of plant pests and other stressors that they will encounter. Congratulations to those universities that are already offering this program. Those that are not should definitely consider establishing it.”

### **Future Directions**

#### ***Societies***

At present, many plant doctors have joined societies serving individual disciplines (agronomy, entomology, plant pathology, etc.) or career paths (arboriculture, crop consulting, landscape plant health, etc.). However, as the number of plant doctors increases, the establishment, first, of national and then international societies dedicated to the advancement of the plant doctor profession through cooperation and exchange of information will undoubtedly take place. The first national plant doctor society, the Plant and

Tree Medicine Society of Taiwan, was established in 2014. These societies will strengthen the self-identities of individual plant doctors and increase their visibility to and recognition by those in government, industry, and the general public. These societies in combination with university-based educational programs could also assist government agencies in developing the process of certification and licensure for plant doctors.

### ***Certification/licensure***

At present, the critical mass of plant doctors in the USA needed for certification and licensure has not been reached. These individuals may seek professional accreditation through such crop consulting organizations as the American Society of Agricultural Consultants (ASAC), Certified Crop Advisors (CCA), and NAICC in the USA; the Association of Independent Crop Consultants (AICC) in the UK; and internationally through the Global Alliance of Independent Agricultural Consultants (GAIAC), or the individual agriscience disciplines that comprise plant medicine. However, the situation in Asia appears to be different. As mentioned previously, if passed the Plant Doctor Law in the Taiwan would establish a national process of certification and licensure for those prescribing medicine for crop health problems. The B.S. in Clinical Plant Science qualifies the recipient for recognition as an “Associate Tree Doctor” and “Associate Nature Restoration Promoter” through the Japan Greenery Research and Development Center (S. Kagiwada, personal communication, July 12, 2015). An Urban Tree Protection amendment to the Forest Law of Taiwan was passed in 2015 which will establish procedures for professional certification of arborists and tree doctors (Dr. E.-J. Sun, personal communication, July 17, 2015).

### ***MOA/MOU***

Memoranda of agreement/understanding between programs and universities should lead to closer communication and cooperation and help to increase the effectiveness and size of individual plant doctor programs. A number of memoranda of agreement/ understanding have been developed which may lead to useful student and faculty exchanges, and joint/dual degree programs. Also formal collaboration between plant doctor programs and other plant health organizations such as the Consultative Group for International Agricultural Research (CGIAR) centers and the Global Plant Clinic managed by the Commonwealth Agricultural Bureaux International (CABI) could result in very productive synergies.

### ***Curriculum evaluations***

Periodic curriculum evaluations following specific institutional guidelines obviously provide an opportunity for training enhancement. Evaluations should include external reviewers such as faculty from other plant doctor programs, program graduates and representatives from government and the agriculture industry. Special attention should be given to improving the quality of and evaluation methods for practicums and internships since these experiences should produce firsthand knowledge about the interaction of all the components of crop health.

### ***Integrated plant clinics***

Integration of pest (insects, pathogens, nematodes, weeds) and plant (soil, water, and plant tissue testing) diagnostic disciplines into a centrally located clinic results in a synergistic improvement of the services offered to clientele, expansion of clientele, and greatly enhances the training of plant doctors and other students. A number of plant diagnostic clinics at universities in the USA are pest-integrated including the Plant Diagnostic Center of Louisiana State University managed by Dr. Raghuwinder Singh, D.P.M. The Clinical Plant Science Center was established at Hosei University in 2014 to serve the plant/crop industry and the general public, to educate plant doctors and to increase support for this program (S. Kagiwada, personal communication, August 22, 2015). A Plant Medical Center is under development at National Chung Hsing University which will provide diagnostic services and pesticide residue testing for government, growers and other industry sectors and the general public. The center will also provide hands-on learning opportunities for student plant doctors (T. P. Huang, personal communication, August 20, 2015). The Plant Medicine Program at National Taiwan University operates a Plant and Tree Clinic for industry and the general public operated by its graduates assisted by current M.S.P.M. students (Dr. E.-J. Sun, personal communication, July 17, 2015).

### ***Recognition and support***

The quest for enough food, fodder, fiber, and plant-based biofuel will require “pulling out all the stops” on the part of the world agricultural community. As Browning wisely observed, superior genetics can reduce a substantial number of biotic and abiotic plant stressors but cannot possibly eliminate all. Skilled plant doctors can help to reduce the remaining crop deficits in a sustainable manner. Greater government, NGO, industry and private sector recognition and support is needed to rapidly develop, expand and increase this effort especially where food shortages are greatest such as in countries in Sub-Saharan Africa and South Asia. Plant doctors trained

through existing programs are of immediate benefit to such countries. A longer term solution would be the establishment of plant doctor programs in universities in the critical areas with linkages to other plant health-related institutions and organizations. Implementation of this plan should not be delayed.

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**Table 1. Plant Doctor Programs**

University	Program	Next higher academic unit	Country	Year estab.	Degree <sup>2</sup>	No. of credits	No. of grads	Contact, email	Website
Andong National University	Dept. of Plant Medicine	School of Bioresource Sciences	South Korea	2007 <sup>1</sup>	B.S.P.M. <sup>3</sup>	108 <sup>5</sup>	200	Dr. Chuleui Jung cjung@andong.ac.kr	<a href="http://eng.andong.ac.kr/html/college1.jsp?PCD=19004&amp;officeCd=19004006001">http://eng.andong.ac.kr/html/college1.jsp?PCD=19004&amp;officeCd=19004006001</a>
Chungbuk National University	Dept. of Plant Medicine	College of Agriculture, Life & Environ. Sciences	South Korea	2004 <sup>1</sup>	B.S.P.M. <sup>3</sup>	115	500	Dr. Byeongjin Cha bjcha@chungbuk.ac.kr	<a href="http://plantmed.cbnu.ac.kr/dsoft/">http://plantmed.cbnu.ac.kr/dsoft/</a>
Sunchon National University	Dept. of Plant Medicine	College of Life Science & Natural Resources	South Korea	2005 <sup>1</sup>	B.S.P.M.	110	350	Dr. Young-Jin Koh youngjin@sunchon.ac.kr	<a href="http://eng.sunchon.ac.kr/web/eng/colleges0103">http://eng.sunchon.ac.kr/web/eng/colleges0103</a>
National Chiayi University	Dept. of Plant Medicine	College of Agriculture	Taiwan	2012	B.S.P.M. <sup>3</sup>	128	120	Dr. C. H. Kuo chkuo@mail.ncyu.edu.tw	<a href="http://www.ncyu.edu.tw/dpm_eng/">http://www.ncyu.edu.tw/dpm_eng/</a>
National Pingtung Univ. of Science and Technology (NPUST)	Dept. of Plant Medicine	College of Agriculture	Taiwan	2009 <sup>1</sup>	B.S.P.M. <sup>3</sup>	136	270	Dr. Lihling Chern llchern@mail.npust.edu.tw	<a href="http://www.npust.edu.tw:8080/Introduce/Introduce_en.aspx?ID=57">http://www.npust.edu.tw:8080/Introduce/Introduce_en.aspx?ID=57</a>
Hosei University	Dept. of Clinical Plant Science	Faculty of Bioscience and Applied Chemistry	Japan	2008	B.S.C.P.S. <sup>3</sup>	124	270	Dr. Satoshi Kagiwada kagiwada@hosei.ac.jp	<a href="http://www.hosei.ac.jp/english/faculty/bioscience/plant/">http://www.hosei.ac.jp/english/faculty/bioscience/plant/</a>
National Chung Hsing University	Master's Program for Plant Medical Science and Safe Agriculture	College of Agriculture and Natural Resources	Taiwan	2015	M.S.P.M.S. - S.A.	50 <sup>6</sup>	-	Dr. Fuh-Jyh Jan fjjan@nchu.edu.tw	<a href="http://pmssa.nchu.edu.tw">http://pmssa.nchu.edu.tw</a>
National Taiwan University	Master's Program for Plant Medicine	College of Bio-Resources and Agriculture	Taiwan	2011	M.S.P.M.	72	16	Dr. En-Cheng Yang ecyang@ntu.edu.tw	<a href="http://140.112.80.34/ntumspm/">http://140.112.80.34/ntumspm/</a>
Ohio State University	Master in Plant Health Management	Dept. of Plant Pathology and Dept. of Entomology	USA	2012, 2014 (online)	M.P.H.M.	35	8	Dr. Monica M. Lewandowski lewandowski.52@osu.edu	<a href="http://mphm.osu.edu/">http://mphm.osu.edu/</a>
University of Florida (UF)	Plant Medicine Program	College of Agricultural and Life Sciences	USA	1999	D.P.M. <sup>4</sup>	100	71	Dr. Amanda C. Hodges achodges@ufl.edu	<a href="http://dpm.ifas.ufl.edu/">http://dpm.ifas.ufl.edu/</a>
University of Nebraska-Lincoln (UN-L)	Doctor of Plant Health Program	College of Agricultural Sciences and Natural Resources	USA	2009	D.P.H. <sup>4</sup>	100	10	Dr. Gary L. Hein ghein1@unl.edu	<a href="http://dph.unl.edu/">http://dph.unl.edu/</a>

Mansoura University	Plant Medicine Program	Faculty of Agriculture	Egypt	In devel.	D.P.M. <sup>5</sup>	100	-	Dr. Yasser Shabana yassershavana2@yahoo.com	-
Northwest Agricultural and Forestry University	Plant Medicine Program	College of Plant Protection	China	In devel.	B.S.P.M. M.S.P.M.	130- 140	-	Dr. Tongxian Liu txliu@nwsuaf.edu.cn	-
Chiang Mai University	Department of Entomology and Plant Pathology	Faculty of Agriculture	Thailand	In devel.	B.S.	110- 120	-	Dr. Chaiwat To-anun chaiwat.toanun@gmail.com	-

<sup>1</sup>Year department or program was renamed

<sup>2</sup>B.S.P.M. = B.S. in Plant Medicine; B.S.C.P.S. = B.S. in Clinical Plant Science; M.S.P.M. = M.S. in Plant Medicine; M.S.P.M.S.-S.A. = M.S. in Plant Medical Science and Safe Agriculture; M.P.H.M. = Master of Plant Health Management; D.P.M. = Doctor of Plant Medicine; D.P.H. = Doctor of Plant Health

<sup>3</sup>Researched-based M.S. and Ph.D. degrees in individual agricultural science disciplines are also offered; at NPUST the degree is called the M.S.P.M.

<sup>4</sup>Joint D.P.M./M.S. and D.P.M./Ph.D.; and D.P.H./M.S. and D.P.H./Ph.D. degrees are options at UF and UN-L, respectively.

<sup>5</sup>160 hours of internship are also required

<sup>6</sup>Includes 6 credits of applied research and a thesis